METAS VNA Tools II - User Manual V1.2

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Contents

1 Installation

1.1 System Requirements

The following list describes the minimum software and hardware requirements of METAS VNA Tools II.

- Microsoft Windows XP
- Microsoft .NET Framework 2.0
- Microsoft Windows Installer 3.1
- National Instruments VISA 5.0.3
- At least 512 megabytes (MB) of RAM (1024 MB is recommended)
- At least 40 megabytes (MB) of available space on the hard disk
- Video adapter and monitor with SVGA (800 x 600) or higher resolution (1280 x 1024 is recommended)

1.2 Steps

The following steps describe the installation of METAS VNA Tools II.

1. Double-click on the METAS VNA Tools II setup program
2. Accept license agreement
3. Select installation folder
4. Confirm installation
5. Installation complete

After the installation, one can start METAS VNA Tools II by double-clicking on its desktop shortcut.

2 Overview

METAS VNA Tools II is a software which is designed to compute uncertainties of S-parameter measurements:

- It uses a VNA measurement model for N-port Vector Network Analyzers.
- It supports the following calibration types: One Port, SOLT, GSOLT, QSOLT, Unknown Thru, TRL, and Optimization.
- It allows the definition of all influences that affect VNA measurements.
- It uses the Linear Propagation module of Metas.UncLib to propagate all uncertainties through the VNA measurement model.
- It can visualize S-parameter data with uncertainties.

The graphical user interface is split up into two parts, see Figure 1. The navigation bar is in the upper part of the screen and below is the tabular control.

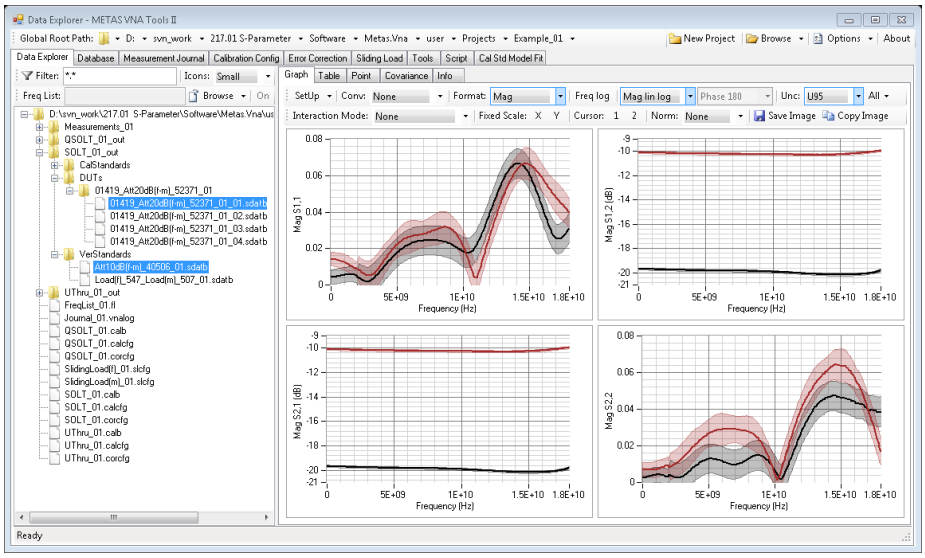


Figure 1: METAS VNA Tools II

2.1 Navigation Bar

The following user controls are available in the navigation bar:

Global Root Path sets the root directory for all tabular pages.

New Project creates a new project, see section 2.1.1.

Browse selects a root directory.

Options sets the METAS VNA Tools II options, see section 2.1.2.

Create Screenshots creates screen shots of all tabular pages.

About shows the about box.

2.1.1 New Project

The dialog called New Project can be used to create a new project, see Figure 2. The following user controls are available:

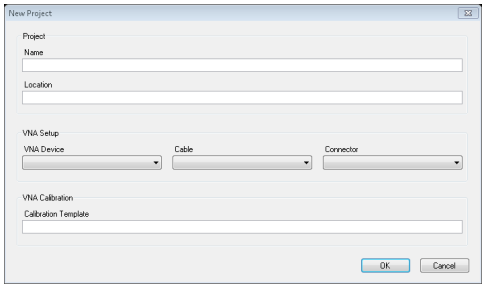


Figure 2: METAS VNA Tools II / New Project

Project Name specifies a name for the new project. A new directory will be created.

Project Location sets the root directory for the new project.

VNA Device selects a VNA device.

Cable selects a cable from the database.

Connector selects a connector from the database.

Calibration Template selects a template for the calibration configuration from the database.

2.1.2 Options

The options dialog can be used to configure the options of METAS VNA Tools II, see Figure 3. The following user controls are available:

Default Root Path sets the root directory.

Default Root Path Database sets the root directory for the database.

Single Instance limits the METAS VNA Tools II application to one instance.

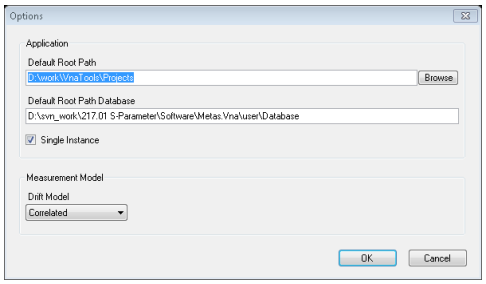


Figure 3: METAS VNA Tools II / Options

Drift Model specifies the used drift model. One can chose the Correlated or Uncorrelated model (default: Correlated). The drift model which is uncorrelated is obsolete and was used in older versions of METAS VNA Tools II (before V0.9). The new drift model (correlated) uses the time stamp of the measurement to compute how big is the drift between multiple measurements.

2.2 Tabular Control

The following tabular pages are available:

Data Explorer is designed to visualize S-parameter files.

Database specifies values and uncertainties of cables, calibration standards, connectors and VNA devices.

Measurement Journal is used to collect measurement data and to protocol the measurement process.

Calibration Config configures a VNA calibration and computes the error terms.

Error Correction configures and computes the error correction of raw measurement data.

Sliding Load configures and computes the circle fit of a sliding load.

Tools provides some tools for post processing of data.

Script provides a built-in Iron Python script engine.

Agilent Model Fit computes the Agilent model parameters for a calibration standard.

3 Data Explorer

The Data Explorer tabular page is designed to visualize S-parameter files. The graphical user interface is split up into two parts. The file explorer is on the left and the visualization with different tabs is on the right.

3.1 Filetypes

Table 1 shows the supported file types. S-Parameter Data files can only contain

Table 1: File types

Description	Extension
S-Parameter Data Binary	(.sdatb)
S-Parameter Data Touchstone	(.s*p)
S-Parameter Data Xml	(.sdatx)
VNA Data Binary	(.vdatb)
VNA Data CITI	(.cti;.citi)
VNA Data Xml	(.vdatx)

S-parameter data. In contrast VNA Data files can contain receiver values and ratios of receiver values.

3.2 File Explorer

The following user controls are available:

Filter sets file filter (default: *.*).

Icons sets icon size (default: Small).

Freq List Browse can be used to select a frequency list file. All selected files in the tree view will be interpolated (default: None).

Freq List On turns frequency list interpolation on or off (default: Off).

Tree View can be used to select one or multiple files. Additional files can be selected while holding the CTRL or SHIFT key.

3.3 Visualization

The Data Explorer supports different view modes:

Graph shows a graphical visualization of multiple files.

Table shows a tabular visualization of a single file.

Point shows an uncertainty budget for one frequency point and one parameter of a single file.

Covariance shows a covariance matrix for a single frequency point or a single parameter of a single file.

Info shows file information including MD5 checksum of multiple files.

3.3.1 Graph

The graph tab supports multiple selected files, see Figure 4. The following user

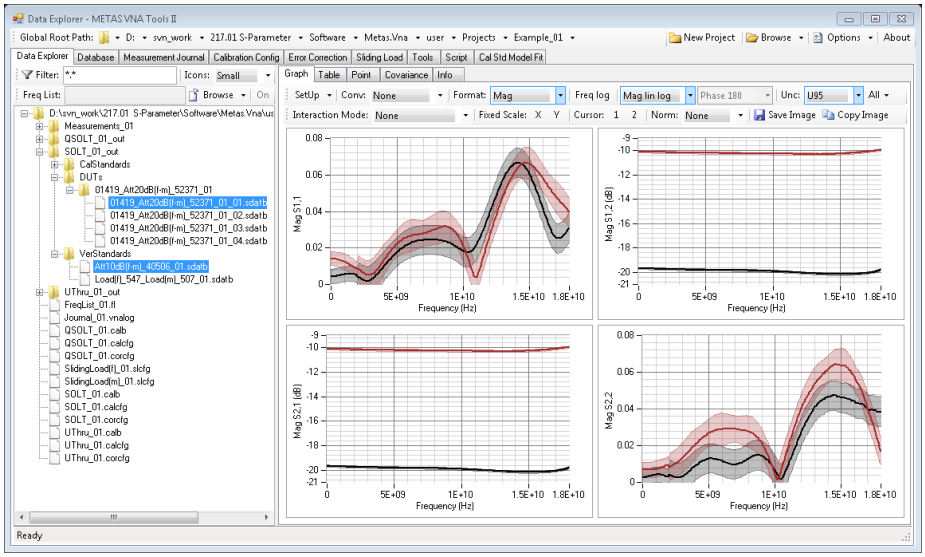


Figure 4: Data Explorer / Graph

controls are available:

SetUp sets up the plots (default: Sx,x Ports: 1, 2).

Conv sets the conversion to None, S/S', Impedance, Admittance, VSWR or Time Domain (default: None).

Format sets the data format to Real Imag, Mag Phase, Real, Imag, Mag, Phase or Cartesian (default: Mag Phase).

Freq log sets the frequency axis to linear or logarithmic (default: Freq lin).

Mag format sets the magnitude format to Mag lin (reflection and transmission linear), Mag log (reflection and transmission logarithmic) or Mag lin log (reflection linear and transmission logarithmic) (default: Mag lin).

Phase format sets the phase format to Phase 180, Phase 360, Phase Unwrap, Phase Delay or Group Delay (default: Phase 180).

Unc sets the uncertainty mode to None, Standard or U95 (default: None).

Interaction Mode sets interaction mode to None, Zoom or Pan (default: None).

Fixed Scale activates or deactivates automatically scaling of the x- and y-axis.

Cursor shows or hides one or two cursors.

Norm normalizes all traces to one selected trace or to the mean value of all traces (default: None).

Save Image saves the current plots to a bitmap file. Supported file formats are BMP, JPG and PNG.

Copy Image copies the current plots to the clipboard.

Table 2 shows the different colors for each trace and its associated uncertainty region.

Table 2: Trace Colors

Trace	Value	Unc	Color
1			black
2			brown
3			red
4			orange
5			yellow
6			green
7			blue
8			violet
9			gray
10			light gray

3.3.2 Table

The first of the selected files will be shown in the table view, see Figure 5. The

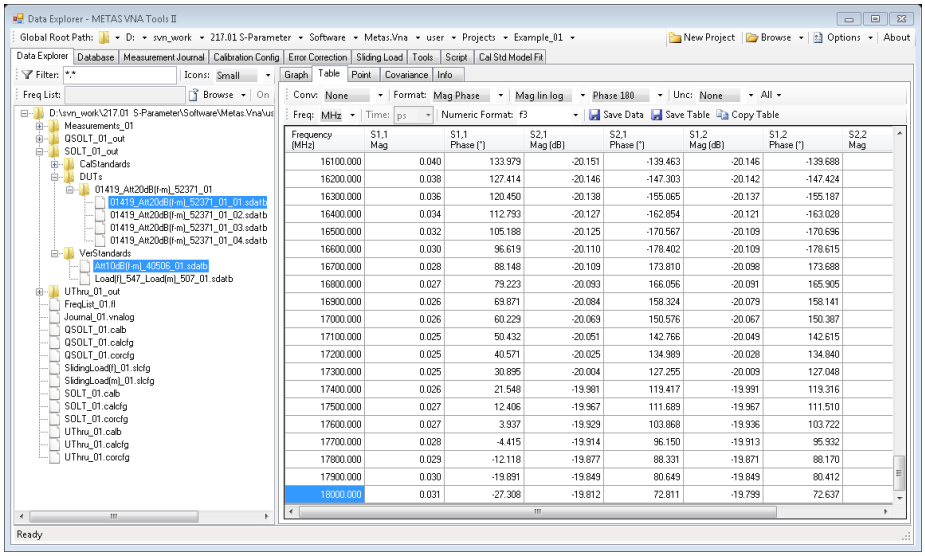


Figure 5: Data Explorer / Table

following user controls are available:

Conv sets the conversion to None, S/S', Impedance, Admittance, VSWR or Time Domain (default: None).

Format sets the data format to Real Imag, Mag Phase or Mag (default: Mag Phase).

Mag format sets the magnitude format to Mag lin (reflection and transmission linear), Mag log (reflection and transmission logarithmic) or Mag lin log (reflection linear and transmission logarithmic) (default: Mag lin).

Phase format sets the phase format to Phase 180, Phase 360, Phase Unwrap, Phase Delay or Group Delay (default: Phase 180).

Unc sets the uncertainty mode to None, Standard or U95 (default: None).

Freq sets the frequency format to Hz, kHz, MHz or GHz (default: MHz).

Numeric Format sets the numeric format (default: f3).

Save Data saves the current data in a file. Supported file formats are S-Parameter Data (*.sdatb or *.sdatx), Touchstone (*.s1p, *.s2p, *.s*p), VNA Data (*.vdatb or *.vdatx) or CITI (*.cti or *.citi).

Save Table saves the current formatted data in a file. Supported file formats are Text (*.txt) or LaTeX(*.tex).

Copy Table copies the current formatted data to the clipboard.

One can select one or more rows of the table and copy the data to the clipboard with CTRL-C or with the context menu of the table. CTRL-A selects all data.

3.3.3 Point

The first of the selected files will be shown in the point view. One can select one frequency point and one parameter and obtains the uncertainty budget of the selected data point, see Figure 6. The following user controls are available:

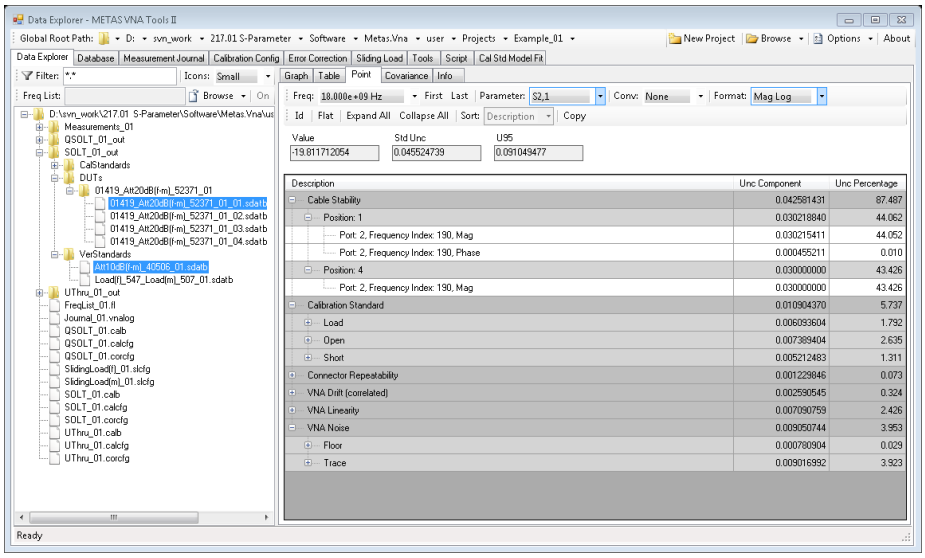


Figure 6: Data Explorer / Point

Freq selects a frequency point for the uncertainty budget (default: None).

Time selects a time point for the uncertainty budget (default: None). Only visible when conversation is set to Time Domain.

First selects the first frequency or time point.

Last selects the last frequency or time point.

Parameter selects a parameter for the uncertainty budget (default: None).

Conv sets the conversion to None, S/S', Impedance, Admittance, VSWR or Time Domain (default: None).

Format sets the format to Real, Imag, Mag, Mag log, Phase, Phase 360, Phase Unwrap, Phase Delay or Group Delay (default: Mag).

Id shows or hides the uncertainty input ids (default: Hide).

Flat shows a flat or tree uncertainty budget (default: Tree).

Expand All expands all tree nodes.

Collapse All collapses all tree nodes.

Sort sets the sort order to Description or Uncertainty (default: Description).

Copy copies the uncertainty budget to the clipboard.

The following items will be shown for the selected data point:

Value indicates the value.

Std Unc shows the standard uncertainty (68% coverage factor, $k = 1$).

U95 shows the expanded uncertainty (95% coverage factor, $k = 2$).

Unc Budget shows a tabular visualization of the uncertainty budget.

3.3.4 Covariance

The first of the selected files will be shown in the covariance view. There are two modes in the covariance view. Either one can select a single frequency point and obtains the covariance matrix of multiple parameters at the selected frequency point. Or one can select all frequency points and a single parameter in the desired format and obtains the covariance matrix for the selected parameter and format over the hole frequency range, see Figure 7. The following user controls are available:

Freq selects a frequency point or all frequency points for the covariance view (default: None).

All selects all frequency points.

First selects the first frequency point.

Last selects the last frequency point.

Parameter selects a parameter for the covariance view (default: None).

Format sets the format to Real, Imag, Mag or Phase (default: Mag).

Mode sets the mode to covariance or correlation (default: Covariance).

Numeric Format sets the numeric format (default: e3).

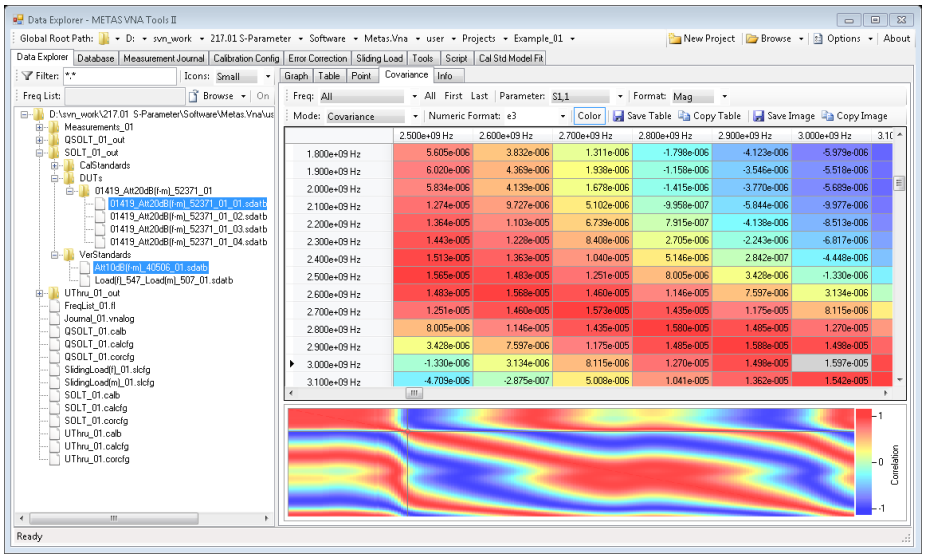


Figure 7: Data Explorer / Covariance

Color shows or hides the graphical representation of the correlation matrix (default: show).

Save Table saves the current formatted covariance in a file. Supported file formats are Text (*.txt) or LaTeX(*.tex).

Copy Table copies the current formatted covariance to the clipboard as text.

Save Image saves the current covariance to a bitmap file. Supported file formats are BMP, JPG and PNG.

Copy Image copies the current covariance to the clipboard as bitmap.

3.3.5 Info

The info tab supports multiple selected files. One can obtain information about multiple files by holding the CTRL or SHIFT key and selecting the files. The info tab shows the file name, size, modification date and computes the MD5 checksum for each selected file. See Figure 8. The following user controls are available:

Size shows or hides the file sizes (default: Show).

Data modified shows or hides the file dates (default: Hide).

Save Table saves the current information in a file. Supported file formats are Text (*.txt) or LaTeX(*.tex).

Copy Table copies the current information to the clipboard.

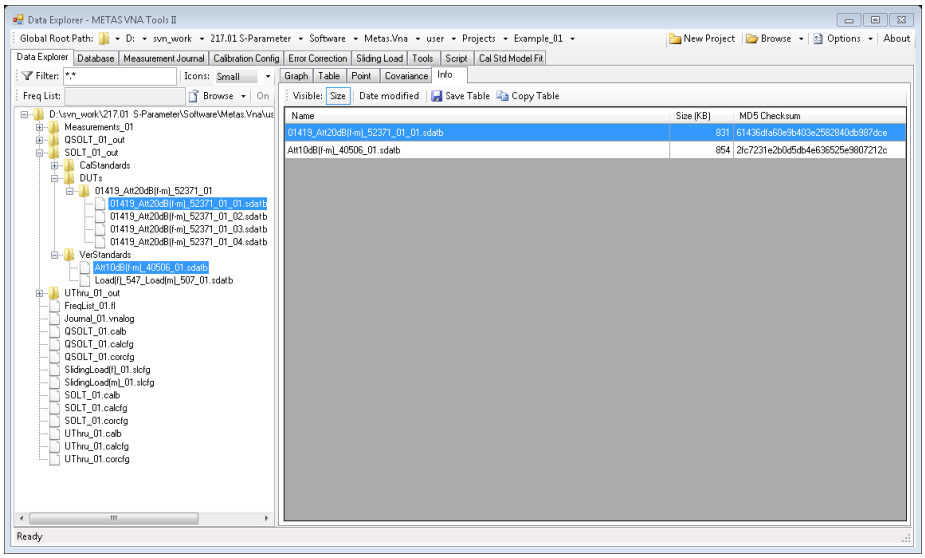


Figure 8: Data Explorer / Info

3.4 Math

The same equations are used in Graph, Table and Point tab for data conversion and formatting. Table 3 shows the equations for data conversions in METAS VNA Data Explorer. Variable x is the input quantity, y is the converted ouptut, Z_r is the reference impedance and Y_r is the reference admittance. Index i is the frequency point, j is the receiver port and k is the source port. Table 4 shows

Table 3: Conversions

Conversion	Equation
None	$y = x$
S/S'	$y_{jk} = x_{jk}/x_{kj}$
Impedance	$y = \frac{1+x}{1-x} Z_r$
Admittance	$y = \frac{1-x}{1+x} Y_r$
VSWR	$y = \frac{1+\lvert x\rvert}{1-\lvert x\rvert}$
Time Domain	$y = \text{ifft}\,(x)$ with 256 points

the equations used for data formatting. Variable y is the converted input from Table 3 and z is the formatted output.

Table 4: Formats

Format	Equation
Real	$z = \Re(y)$
Imag	$z = \Im(y)$
Mag	$z = \lvert y \rvert$
Mag log	$z = 20 \log_{10}(\lvert y \rvert)$
Phase	$z = \arg(y)$
Phase 360	$z = \arg(y)$
Phase Unwrap	$z = \mathrm{unwrap}(\arg(y))$
Phase Delay	$z_i = -\frac{\varphi_i}{2\pi f_i}$ with $\varphi = \mathrm{unwrap}(\arg(y))$
Group Delay	$z_i = -\frac{\varphi_i - \varphi_{i-1}}{2\pi(f_i - f_{i-1})}$ with $\varphi = \mathrm{unwrap}(\arg(y))$

3.5 Uncertainty

There are three different uncertainty modes:

None hides the uncertainty.

Standard shows the standard uncertainty. In a scalar case this means 68% coverage and $k = 1$. In a two dimensional case this means 39% coverage and $k = 1$.

U95 shows the expanded uncertainty. In a scalar case this means 95% coverage and $k = 2$. In a two dimensional case this means 95% coverage and $k = 2.45$.

Here a scalar quantity consist of only one component, e.g. magnitude of S-parameter, whereas a two dimensional quantity consists of two components, e.g. complex S-parameter. In graphical representations the dimension is determined by the number of components shown in one subplot.

The uncertainties are computed with linear uncertainty propagation. This leads to well known problems when computing the absolute value and phase of small quantities.

4 Database

The Databased is designed to specify values and uncertainties of cables, calibration standards, connectors and VNA devices.

4.1 Cable

The tabular page, called Cable, is designed to specify cables in the database, see Figure 9. The following user controls are available:

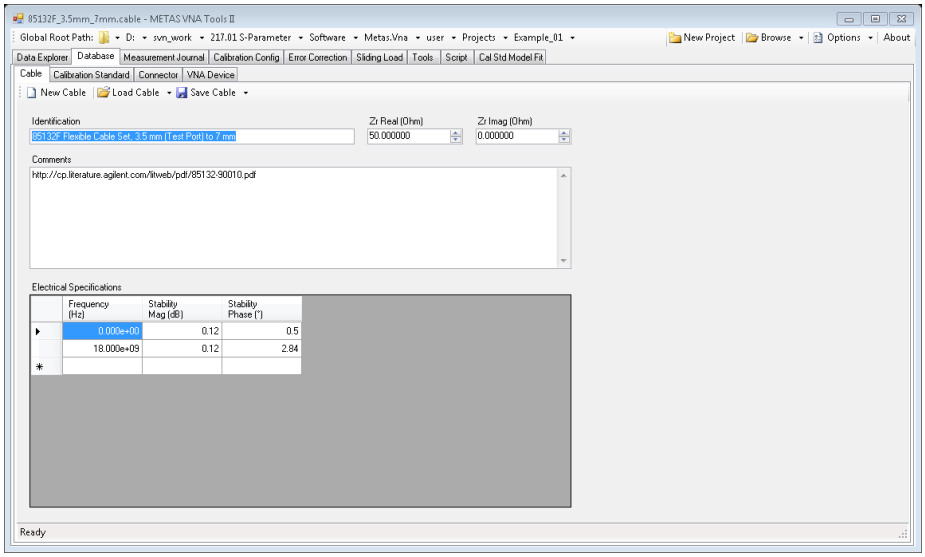


Figure 9: Database / Cable

New Cable creates a new database item of the type cable.

Load Cable loads a cable from a file (*.cable).

Save Cable saves the cable to a file (*.cable).

Identification field can contain an identification string.

Zr Real (Ohm) specifies the real part of the reference impedance in Ohm.

Zr Imag (Ohm) specifies the imaginary part of the reference impedance in Ohm.

Comments field can contain user comments.

Electrical Specifications is a table with the following columns:

- Frequency in Hz

- Stability Mag (dB) with $k = 2$
- Stability Phase (deg) with $k = 2$

4.2 Calibration Standard

The tabular page, called Calibration Standard, is designed to specify calibration standards in the database, see Figure 10. The following user controls are

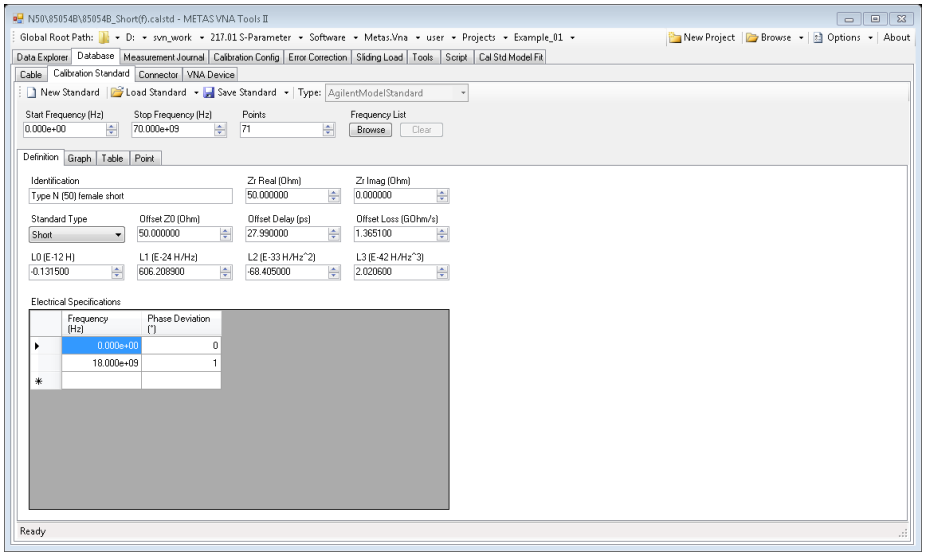


Figure 10: Database / Calibration Standard

available:

New Standard creates a new database item of the type calibration standard. For a databased standard see section 4.2.3.

Load Standard loads a calibration standard from a file (*.calstd).

Save Standard saves the calibration standard to a file (*.calstd).

Start Frequency (Hz) specifies the start frequency.

Stop Frequency (Hz) specifies the stop frequency.

Points sets the number of data points.

Frequency List Browse loads a frequency list.

Frequency List Clear clears the frequency list.

Identification field can contain an identification string.

Zr Real (Ohm) specifies the real part of the reference impedance in Ohm.

Zr Imag (Ohm) specifies the imaginary part of the reference impedance in Ohm.

4.2.1 Agilent Model Standard

For a calibration standard of the type Agilent model the following controls are available:

Standard Type specifies the standard type as open, short, load or delay/thru.

Offset Z0 (Ohm) sets the offset line impedance in Ohm.

Offset Delay (ps) sets the offset line delay in ps.

Offset Loss (GOhm/s) set the offset line loss in GOhm/s.

C0 (E-15 F) sets the first polynomial coefficient for an open.

C1 (E-27 F/Hz) sets the second polynomial coefficient for an open.

C2 (E-36 F/Hz^2) sets the third polynomial coefficient for an open.

C3 (E-45 F/Hz^3) sets the fourth polynomial coefficient for an open.

L0 (E-12 H) sets the first polynomial coefficient for a short.

L2 (E-24 H/Hz) sets the second polynomial coefficient for a short.

L2 (E-33 H/Hz^2) sets the third polynomial coefficient for a short.

L3 (E-42 H/Hz^3) sets the fourth polynomial coefficient for a short.

Electrical Specifications is a table with the following columns for an open or a short:

- Frequency in Hz
- Phase Deviation (deg) with $k = 2$

Phase deviations are as well translated to magnitude uncertainties. The used formalism yields a circular uncertainty region.

For a load or delay/thru the table has the following columns:

- Frequency in Hz
- Return Loss (dB) with $k = 2$

E.g. an uncertainty of the Return Loss of -40 dB is translated to an uncertainty of 0.01 of real and imaginary part of the reflection coefficient.

4.2.2 Databased Standard

Databased standards define the value and uncertainty budget of each frequency point and parameter. This format works without loss of accuracy. Thus it is ideal for transferring measurement data and uncertainties from National Metrology Institutes to customers. For a databased standard the following control is available:

Data Path specifies the file path (*.sdatb) which contains the S-parameters of the standard.

4.2.3 New Database Standard Wizard

The wizard called New Database Standard is designed to create a new databased standard, see Figure 11. The following user controls are available:

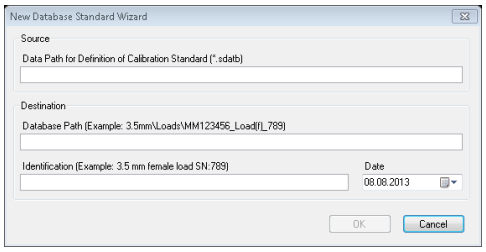


Figure 11: Database / New Database Standard Wizard

Data Path for Definition of Calibration Standard specifies the source file (*.sdatb) for the definition of the calibration standard.

Database Path specifies the destination in the database (Example: 3.5mm\Loads\MM123456_Load(f)_789).

Identification field can contain an identification string (Example: 3.5 mm female load SN:789).

Date sets the date. This date is part of the name of the databased standard.

4.3 Connector

The Connector tabular page is designed to specify connectors in the database, see Figure 12. The following user controls are available:

New Connector creates a new database item of the type connector.

Load Connector loads a connector from a file (*.conn).

Save Connector saves the connector to a file (*.conn).

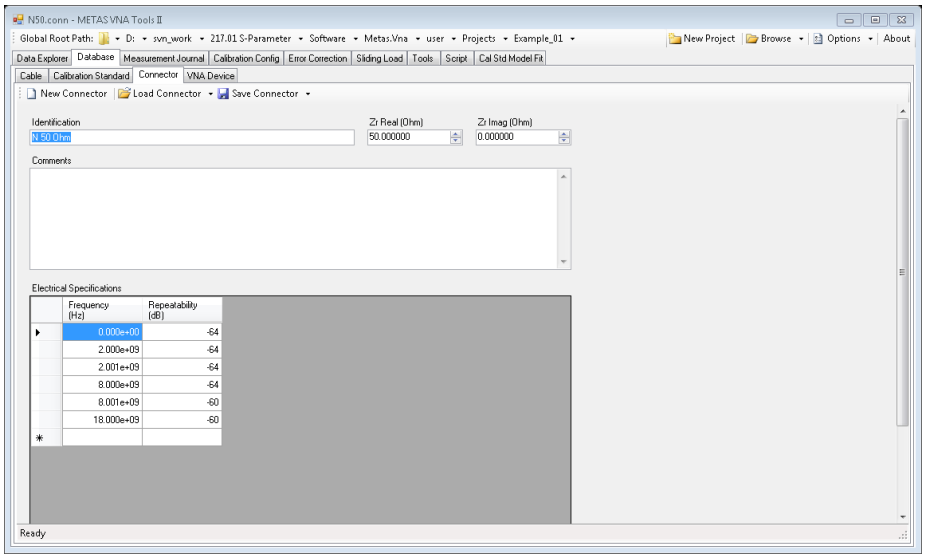


Figure 12: Database / Connector

Identification field can contain an identification string.

Zr Real (Ohm) specifies the real part of the reference impedance in Ohm.

Zr Imag (Ohm) specifies the imaginary part of the reference impedance in Ohm.

Comments field can contain user comments.

Electrical Specifications is a table with the following columns:

- Frequency in Hz
- Repeatability (dB) with $k = 2$

4.4 VNA Device

The VNA Device tabular page is designed to specify VNA devices in the database, see Figure 13. The following user controls are available:

New VNA creates a new database item of the type VNA device.

Load VNA loads a VNA item from a file (*.vnadev).

Save VNA saves the VNA item to a file (*.vnadev).

Find Resources finds VISA resources. VISA resources are the addresses of devices connected to the computer. VISA is a standard which is accepted by nearly all manufactures of VNAs.

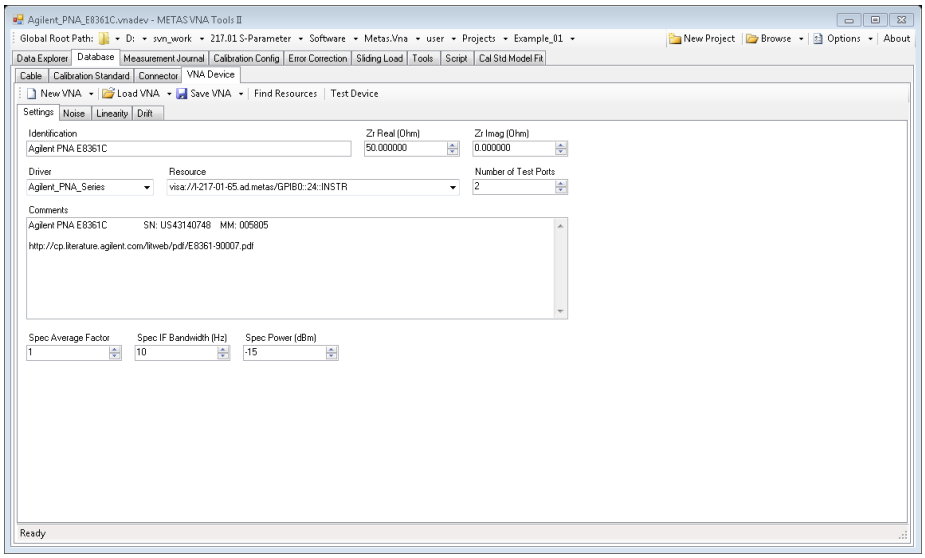


Figure 13: Database / VNA Device / Settings

Test Device tests VNA device if VISA connection is possible.

The following user controls are available on the sub tabular page called Settings:

Identification field can contain an identification string.

Zr Real (Ohm) specifies the real part of the reference impedance in Ohm.

Zr Imag (Ohm) specifies the imaginary part of the reference impedance in Ohm.

Driver sets the driver for the communication with the VNA device.

Resource sets the VISA resource name of the VNA device.

Number of Test Ports specifies the number of test ports.

Comments field can contain user comments.

Spec Average Factor specifies the average factor used for the noise specification.

Spec IF Bandwidth (Hz) specifies the IF bandwidth used for the noise specification.

Spec Power (dBm) specifies the power level used for the noise floor and linearity specification.

The next sub tabular page is called Noise, see Figure 14. It contains a table with the following columns:

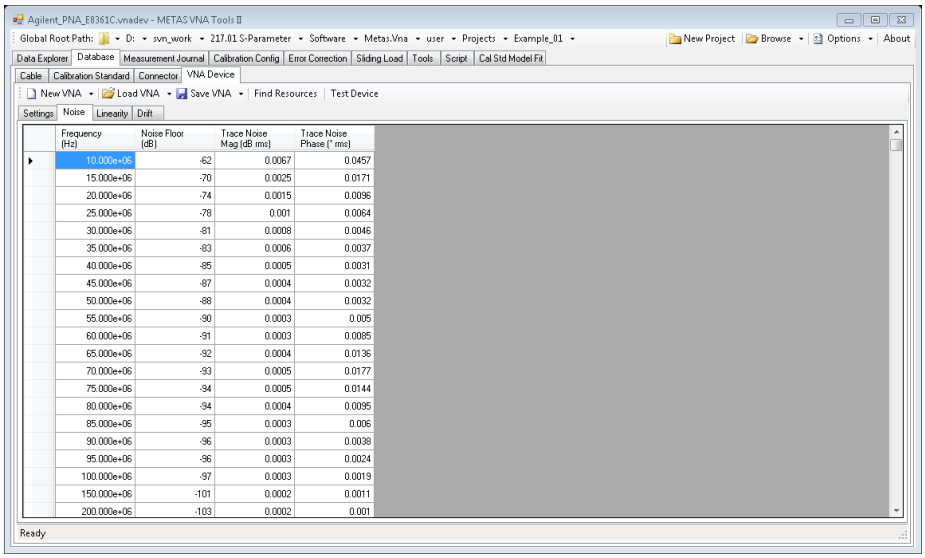


Figure 14: Database / VNA Device / Noise

- Frequency (Hz)
- Noise Floor (dB) with $k = 2$
- Trace Noise Mag (db rms) with $k = 1$
- Trace Noise Floor (deg rms) with $k = 1$

The next sub tabular page contains two tables and is called Linearity, see Figure 15. The first specifies the different power levels in dB. The second table contains the following columns:

- Frequency (Hz)
- Linearity Mag (dB) with $k = 2$, one column for each power level
- Linearity Phase (deg) with $k = 2$, one column for each power level

The next sub tabular page is called Drift, see Figure 16. It contains a table with the following columns:

- Frequency (Hz)
- Switch Term Drift (dB) with $k = 2$
- Directivity Drift (db) with $k = 2$
- Tracking Drift Mag (dB) with $k = 2$
- Tracking Drift Phase (deg) with $k = 2$

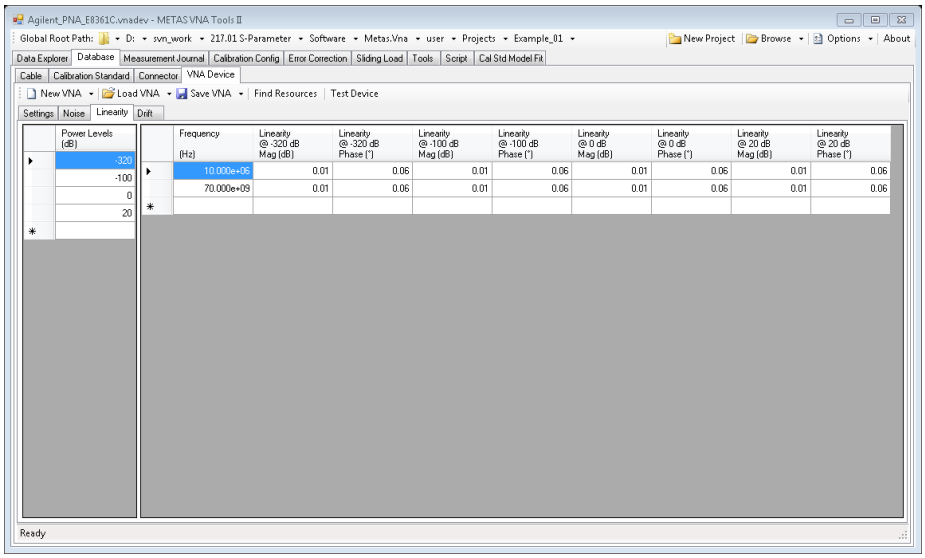
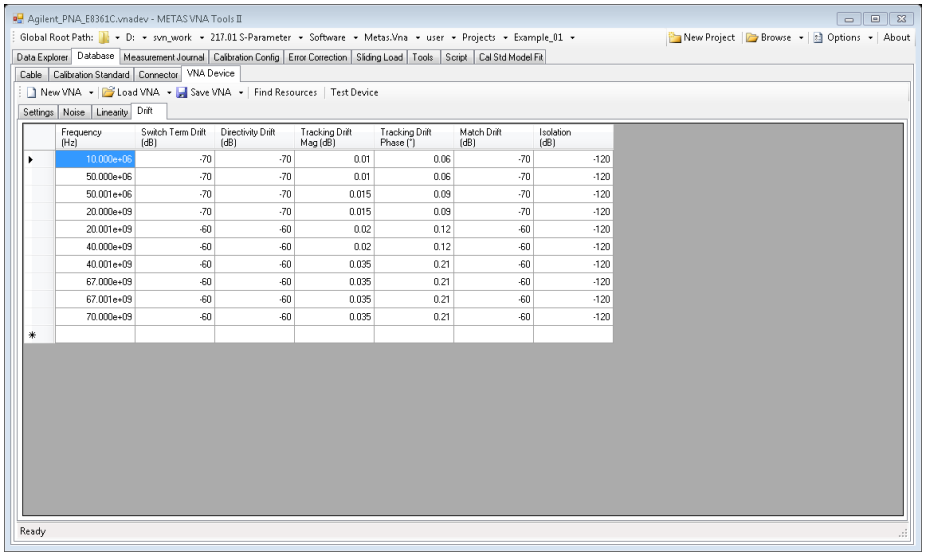


Figure 15: Database / VNA Device / Linearity

- Match Drift (dB) with $k = 2$
- Isolation Drift (dB) with $k = 2$



Frequency (Hz)	Switch Term Drift (dB)	Directivity Drift (dB)	Tracking Drift Mag (dB)	Tracking Drift Phase (°)	Match Drift (dB)	Isolation (dB)
10.000e+06	-70	-70	0.01	0.06	-70	-120
50.000e+06	-70	-70	0.01	0.06	-70	-120
50.001e+06	-70	-70	0.015	0.09	-70	-120
20.000e+09	-70	-70	0.015	0.09	-70	-120
20.001e+09	-60	-60	0.02	0.12	-60	-120
40.000e+09	-60	-60	0.02	0.12	-60	-120
40.001e+09	-60	-60	0.035	0.21	-60	-120
67.000e+09	-60	-60	0.035	0.21	-60	-120
67.001e+09	-60	-60	0.035	0.21	-60	-120
70.000e+09	-60	-60	0.035	0.21	-60	-120

Figure 16: Database / VNA Device / Drift

5 Measurement Journal

The tabular page, called Measurement Journal, is designed to collect measurement data and to protocol the measurement process, see Figure 17. The follow-

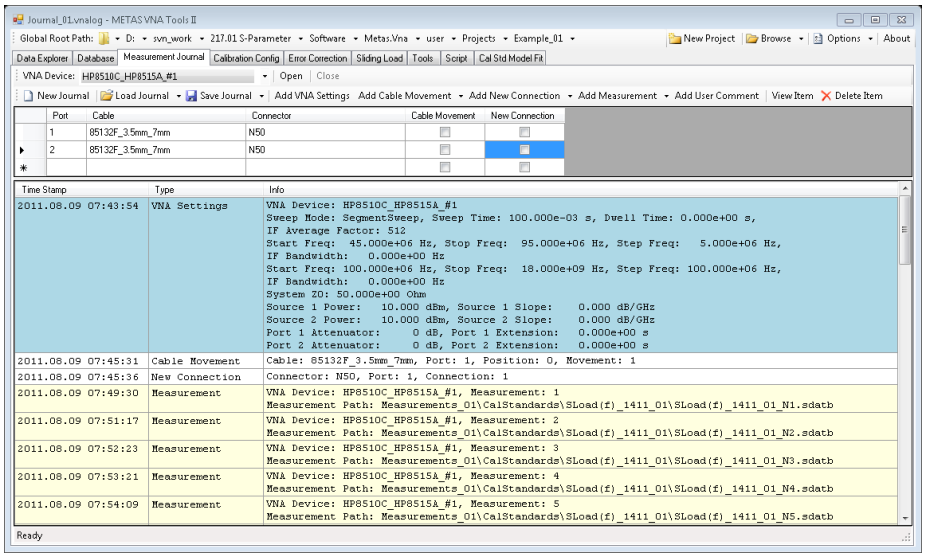


Figure 17: Measurement Journal

ing user controls are available:

VNA Device selects a VNA device.

Open opens the VISA connection to the VNA device.

Close closes the VISA connection to the VNA device.

New Journal creates a new measurement journal.

Load Journal loads an existing measurement journal from a file (*.vnalog).

Save Journal saves the measurement journal to a file (*.vnalog).

Auto Save enables or disables auto save of the measurement journal.

Add VNA Settings adds a journal item for VNA settings to the measurement journal, see 5.1.

Add Cable Movement adds a journal item for cable movement to the measurement journal, see 5.2.

Add Custom Cable Settings specifies a cable for the current journal which is not in the database, see 5.3.

Add New Connection adds a journal item for a new connection to the measurement journal, see 5.4.

Add Custom Connector Settings specifies a connector for the current journal which is not in the database, see 5.5.

Add Measurement adds a measurement entry to the journal, see 5.6.

Add Begin Experiment defines the start of an experiment, see 5.7.

Add End Experiment defines the end of an experiment.

Add Measurement Series adds an entry for a series of measurements to the journal, see 5.8.

Add User Comment adds a user comment to the measurement journal, see 5.9.

View Item shows the selected item of the journal.

Delete Item deletes the selected items of the journal.

Cable and Connector Table specifies the test port cable and connector for each port.

Cable movement adds one or multiple entries in the measurement journal for cable movements at the selected ports before the measurement.

New connection adds one or multiple entries in the measurement journal for new connections at the selected ports before the measurement.

5.1 VNA Settings

The dialog, called VNA Settings, is designed to set up the VNA, see Figure 18. The following user controls are available:

Time Stamp specifies the time stamp for the journal item.

VNA Device specifies the VNA device.

Preset presets the VNA.

Save Instrument State saves the instrument state from the VNA to a file (*.is).

Recall Instrument State recalls the instrument state from a file (*.is) to the VNA.

Refresh refresh all settings from the VNA.

Sweep Mode sets the sweep mode to linear frequency, log frequency, segment sweep or CW time.

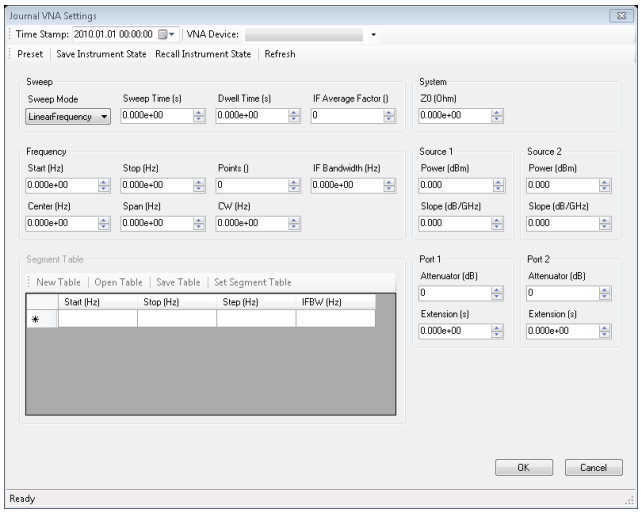


Figure 18: Measurement Journal / VNA Settings

Sweep Time (s) sets the sweep time in s.

Dwell Time (s) sets the dwell time in s.

IF Average Factor sets the average factor.

Start Frequency (Hz) sets the start frequency in Hz.

Stop Frequency (Hz) sets the stop frequency in Hz.

Points sets the number of sweep points.

IF Bandwidth (Hz) sets the IF bandwidth in Hz.

Center Frequency (Hz) sets the center frequency in Hz.

Frequency Span (Hz) sets the frequency span in Hz.

CW Frequency (Hz) sets the frequency for CW sweep mode in Hz.

New Table creates a new segment table.

Open Table loads a segment table from a file (*.txt).

Save Table saves the segment table to a file (*.txt).

Set Segment Table sets the segment table to the VNA.

Segment Table is a table with the following columns:

- Start Frequency in Hz

- Stop Frequency in Hz
- Step Size in Hz
- IF Bandwidth in Hz

System Z0 (Ohm) specifies the reference impedance in Ohm.

Source 1 Power (dBm) sets the power level of the first source in dBm.

Source 1 Slope (dB/GHz) sets the slope of the first source in dB/GHz.

Source 2 Power (dBm) sets the power level of the second source in dBm.

Source 2 Slope (dB/GHz) sets the slope of the second source in dB/GHz.

Port 1 Attenuator (dB) sets the attenuation of the first port in dB.

Port 1 Extension (s) shifts the reference plane of port 1 by a definable delay in s.

Port 2 Attenuator (dB) sets the attenuation of the second port in dB.

Port 2 Extension (s) shifts the reference plane of port 2 by a definable delay in s.

5.2 Cable Movement

The dialog, called Cable Movement, is designed to describe a cable movement for the journal, see Figure 19. The following user controls are available:

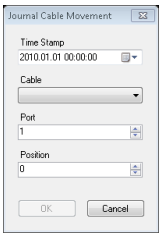


Figure 19: Measurement Journal / Cable Movement

Time Stamp specifies the time stamp of the journal item.

Cable selects a cable from the database.

Port specifies at which port the cable was moved.

Position specifies the position of the cable. Thus each cable movement requires an increase of the position number. With each change of the position number the cable uncertainties, specified in the database, are added to the measurement data.

5.3 Custom Cable Settings

The dialog, called Custom Cable Settings, is designed to describe cables which are not in the database for the current journal. One can specify the magnitude and phase stability of such a cable in this dialog, see Figure 20. The following

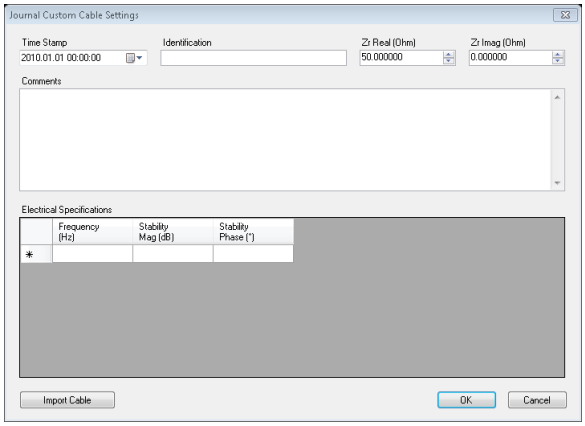


Figure 20: Measurement Journal / Custom Cable Settings

user controls are available:

Time Stamp specifies the time stamp of the journal item.

Identification field contains identification string.

Zr Real (Ohm) specifies the real part of the reference impedance in Ohm.

Zr Imag (Ohm) specifies the imaginary part of the reference impedance in Ohm.

Comments field can contain user comments.

Electrical Specifications is a table with the following columns:

- Frequency in Hz
- Stability Mag (dB) with $k = 2$
- Stability Phase (deg) with $k = 2$

Import Cable imports a cable from the database.

5.4 New Connection

The dialog, called New Connection, is designed to describe a new connection in the journal, see Figure 21. The following user controls are available:

Time Stamp specifies the time stamp of the journal item.

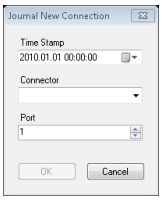


Figure 21: Measurement Journal / New Connection

Connector selects a connector from the database.

Port specifies at which port the new connection was made.

5.5 Custom Connector Settings

The dialog, called Custom Connector Settings, is designed to describe a connector which is not in the database for the current journal. One can specify the repeatability of such a connector in this dialog, see Figure 22. The following

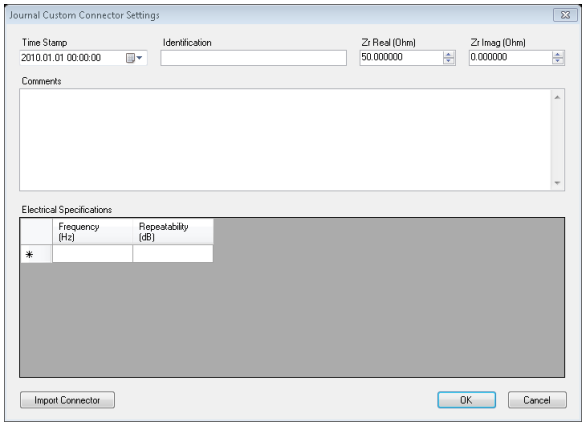


Figure 22: Measurement Journal / Custom Connector Settings

user controls are available:

Time Stamp specifies the time stamp of the journal item.

Identification field can contain an identification string.

Zr Real (Ohm) specifies the real part of the reference impedance in Ohm.

Zr Imag (Ohm) specifies the imaginary part of the reference impedance in Ohm.

Comments field can contain user comments.

Electrical Specifications is a table with the following columns:

- Frequency in Hz
- Repeatability (dB) with $k = 2$

Import Connector imports a connector from the database.

5.6 Measurement

The Measurement dialog is designed to collect measurement data from the VNA, see Figure 23. The following user controls are available:

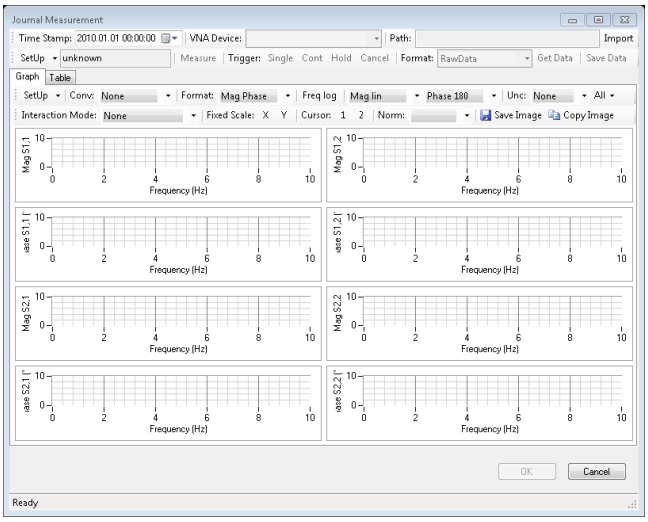


Figure 23: Measurement Journal / Measurement

Time Stamp specifies the time stamp of the journal item.

VNA Device specifies the VNA device.

Path field contains the path of the measurement data.

Import imports an existing file instead of making a new VNA measurement. Only available if VNA connection is closed.

Mode selects a setup mode for the VNA, e.g. S1,1.

SetUp sets up the VNA to the selected mode.

Measure performs a single sweep on the VNA, wait until the sweep is complete and reads out the data.

Trigger Single performs a single sweep on the VNA and waits until the sweep is complete.

Trigger Cont sets the trigger of the VNA to continuous mode.

Trigger Hold sets the trigger of the VNA to hold mode.

Trigger Cancel cancels the current sweep.

Format sets the format to Raw Data or Error Corrected Data (default: Raw Data).

Get Data reads out the data from the VNA.

Save Data saves the data to an S-parameter file (*.sdatb).

5.7 Experiment

The Experiment dialog is designed to describe an experiment, see Figure 24. Experiments are necessary for DUTs with bad repeatability. The journal items of the type experiment will cause VNA Tools II to determine the repeatability of the measurement from repeated measurements. If no journal items of the type experiment are used, the repeatability uncertainties from the database will be used. The following user controls are available:

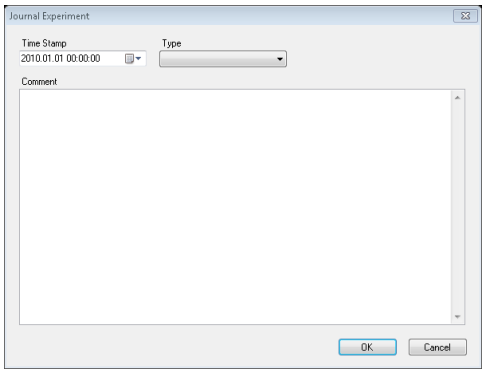


Figure 24: Measurement Journal / Experiment

Time Stamp specifies the time stamp of the journal item.

Type sets the type of the experiment to Statistical or Systematic (default: Systematic). Statistical assumes a mono modal distribution for the resulting uncertainties. Systematic assumes a multi modal distribution.

Comments field can contain user comments.

5.8 Measurement Series

The dialog, called Measurement Series, is designed to collect a series of measurements, see Figure 25. The following user controls are available:

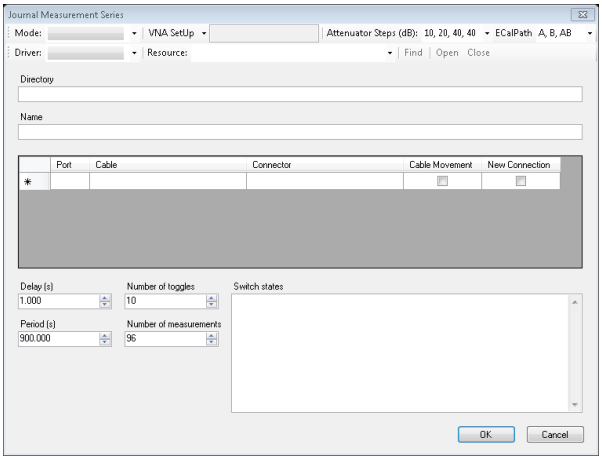


Figure 25: Measurement Journal / Measurement Series

Mode sets the mode of the measurement series. The following modes are available: DUT, Sliding Load, Step Attenuator, Switch States, ECal, Drift and ECal Drift.

VNA SetUp sets up the VNA to the selected mode.

Attenuator Steps (dB) specifies the attenuator steps in dB for a measurement series of the type step attenuator. Multiple steps are comma separated, e.g. '10, 20, 40, 40'.

ECal Path specifies the path of the ECal where all states will be measured. Multiple paths are comma separated, e.g. 'A', 'B', 'AB'. Where 'A' and 'B' are reflection paths and 'AB' is a transmission path.

Driver sets the driver for the communication with the Switch or ECal device.

Resource sets the VISA resource name of the Switch or ECal device.

Find finds VISA resources. VISA resources are the addresses of devices connected to the computer.

Open opens the VISA connection to the Switch or ECal device.

Close close the VISA connection to the Switch or ECal device.

Directory sets the parent directory that will contain the directory of the measurement series.

Name specifies a name for the measurement series. A directory will be created with this name.

Cable and Connector Table specifies the used test port cable and connector for each port.

Cable movement adds one or multiple entries for cable movements at the selected ports in the measurement journal before the measurement series.

New connection adds one or multiple entries for new connections at the selected ports in the measurement journal before the measurement series.

Delay (s) sets the delay between switching states and start of the measurements in s (default: 1 s).

Number of toggles sets the number of switching cycles that are performed on the step attenuator before the measurement series is started (default: 10).

Period (s) sets the period between measurements for drift evaluation in s (default: 900 s).

Number of measurements sets the number of measurements for drift evaluations (default: 96).

Switch states sets the list of switch states which will be measured. Each line in this text box specifies one state. '0' is off, '1' is on and 'x' is don't change.

5.9 User Comment

The dialog, called User Comment, is designed to add user comments to the journal, see Figure 26. The following user controls are available:

Time Stamp specifies the time stamp of the journal item.

Comments field can contain user comments.

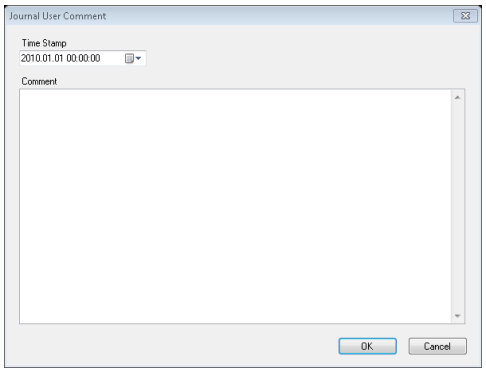


Figure 26: Measurement Journal / User Comment

6 Calibration Config

The tabular page, called Calibration Config, is designed to configure a VNA calibration. The result will be the switch and error terms of the VNA. There are two models of the VNA:

Generic Model stores the switch terms in a N-port and the error terms are stored in a $2N$-port for a N-port VNA. For a two port VNA, this calibration model is known as 7-term model. It supports the following calibration types: One Port, GSOLT, QSOLT, Unknown Thru, TRL (only 2-port) and Optimization (not in external version).

Switched Model stores the error terms in a $2N$-port for each switch position for a N-port VNA. For a two port This model is used for the SOLT calibration.

The following S-parameter matrix describes the calibration error terms of a N-port VNA.

$$\begin{pmatrix} D_1 & X_{1,2} & & X_{1,N} & T_{1,} & & & \\ X_{2,1} & D_2 & & X_{2,N} & & T_{2,} & & \\ & & \ddots & & & & \ddots & \\ X_{N,1} & X_{N,2} & & D_N & & & & T_{N,} \\ T_{,1} & & & & M_1 & & & \\ & T_{,2} & & & & M_2 & & \\ & & \ddots & & & & \ddots & \\ & & & T_{,N} & & & & M_N \end{pmatrix}$$

D_x denotes the directivity of port x.

$X_{y,x}$ denotes the crosstalk from port x to port y.

$T_{x,x}$ denotes the reflection tracking of port x.

$T_{y,x}$ denotes the transmission tracking from port x to port y where $T_{y,x} = T_{y,}T_{,x}$.

M_x denotes the match of port x and all other terms are additional crosstalk terms.

On the tabular page, called Calibration Config, the following user controls are available, see Figure 27:

New creates a new calibration configuration.

New from Template loads a configuration template.

Load Config loads an existing configuration from a file (*.calcfg).

Save Config saves the configuration to a file (*.calcfg).

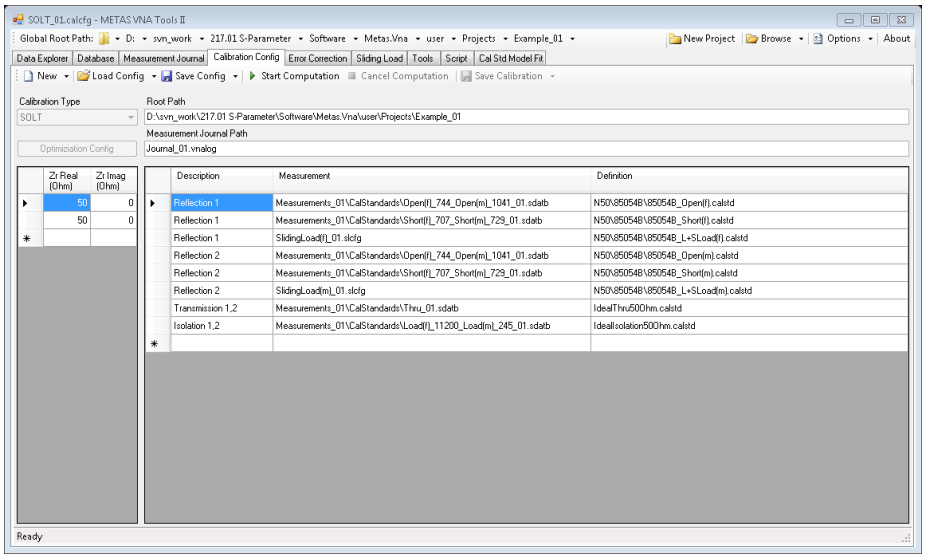


Figure 27: Calibration Config

Start Computation computes the VNA calibration.

Cancel Computation cancels the computation.

Save Calibration saves the VNA calibration to a file (*.calb).

Save Error Terms saves the error terms to a file (*.sdatb). Only available in the generic model.

Save Switch Terms saves the switch terms to a file (*.sdatb). Only available in the generic model.

Save Switched Error Terms saves the error terms for each switch position to a file (*.sdatb).

Optimization Config edits the optimization parameters (not in external version).

Root Path sets the root path for the calibration configuration .

Measurement Journal Path sets the path (*.vnalog) for the measurement journal. All measurements used for the calibration have to be in the measurement journal.

Zr (Ohm) specifies the complex reference impedance for each test port.

Description specifies the type of calibration standard and the ports which were measured.

Measurement specifies the path (*.sdatb) where the data of the measured standard is. Only the configuration (*.slcfg) is given for the sliding load. It is possible to specify an N-port file for 1-port standards. In such a case the number in the description field defines which part of the data is used. E.g. only S1,1 of a 2-port file is used in a line where the description field is set to Reflection 1.

Definition specifies the path (*.calstd) which contains the definition of the standard. Leave this cell empty for a switch term row.

6.1 Optimization Parameters

The dialog, called Optimization Calibration Config, is designed to configure the optimization parameters, see Figure 28. The following user controls are

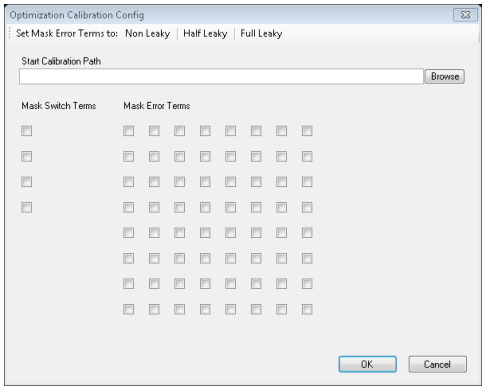


Figure 28: Optimization Calibration Config

available:

Set Mask Error Terms sets the mask of the error terms for a non-, half- or full-leaky model of the VNA.

Start Calibration Path specifies the start values used for the optimization (*.calb).

Mask Switch Terms selects the switch terms which will be optimized.

Mask Error Terms selects the error terms which will be optimized. This mask represents a $2N \times 2N$ S-parameter matrix for a VNA with N ports. In the upper left part of the matrix are the directivity and isolation terms. The match terms are in the lower right of the diagonal. The other check boxes represent tracking terms.

7 Error Correction

The tabular page, called Error Correction, is designed to configure the error correction of the raw measurement data, see Figure 29. The following user

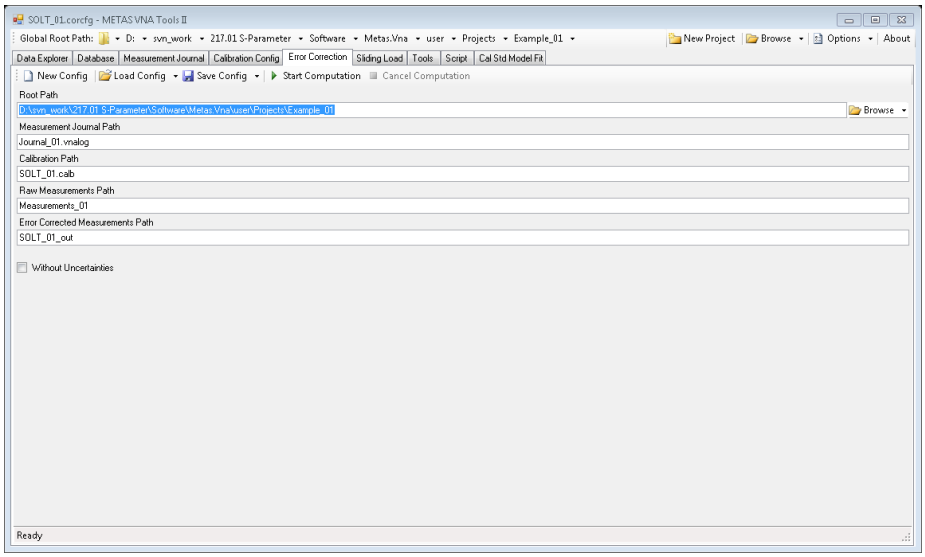


Figure 29: Error Correction

controls are available:

New creates a new configuration for error correction.

Load Config loads an existing configuration from a file (*.corcfg).

Save Config saves the configuration to a file (*.corcfg).

Start Computation computes the error correction.

Cancel Computation cancels the computation.

Root Path sets the root path for the configuration of the error correction.

Measurement Journal Path sets the path (*.vnalog) for the measurement journal. All raw measurements have to be in the measurement journal.

Calibration Path sets the calibration path (*.calb).

Raw Measurement Path sets the directory which contains the raw data.

Error Corrected Measurement Path specifies the path where the error-corrected data will be stored. All files from the Raw Measurement Path and all subdirectories will be error-corrected and stored in this directory.

Without Uncertainties disables uncertainty propagation.

8 Sliding Load

The tabular, page called Sliding Load, is designed to configure and compute the circle fit of a sliding load. It merges the circle fit with the measurement of a low-band load at the specified frequency point, see Figure 30. The following

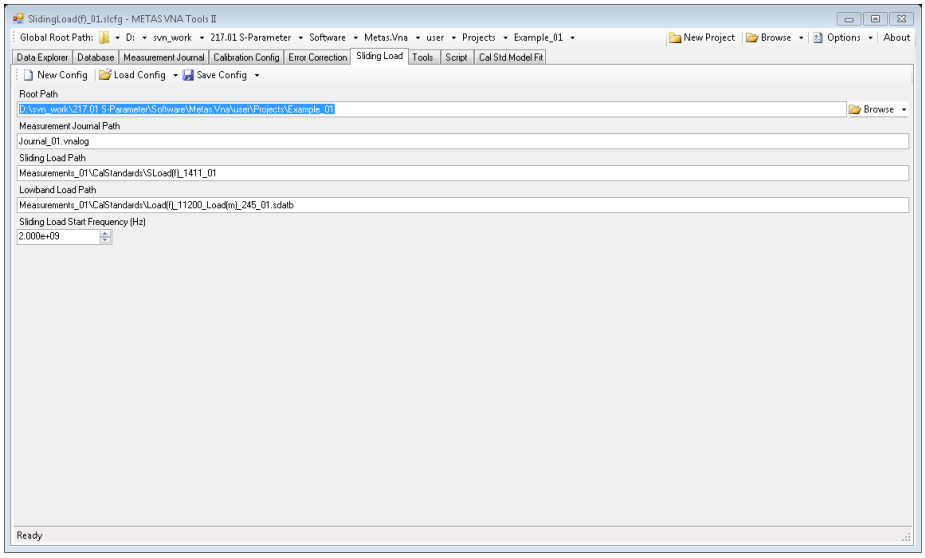


Figure 30: Sliding Load

user controls are available:

New creates a new configuration for a sliding load.

Load Config loads an existing configuration from a file (*.slcfg).

Save Config saves the configuration to a file (*.slcfg).

Root Path sets the root path for the configuration.

Measurement Journal Path sets the path (*.vnalog) for the measurement journal. The files of the sliding load and the low-band load have to be in the measurement journal.

Sliding Load Path sets the directory where the raw measurements of the sliding load are.

Lowband Load Path sets the path (*.sdatb) where the file of the raw measurement of the low-band load is.

Sliding Load Start Frequency (Hz) sets the start frequency of the sliding load in Hz. Below this frequency the measurement data of the low band load is used.

9 Tools

The tabular page, called Tools, provides some tools for post processing of data, see Figure 31. During post processing the uncertainties are propagated to the end results.

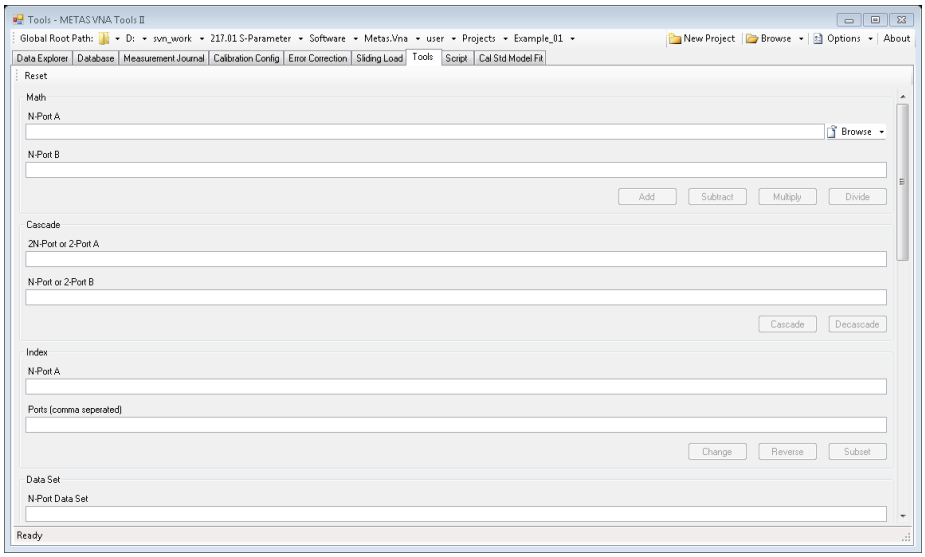


Figure 31: Tools

9.1 Math

The following math tools are available:

Add adds N-port A and N-port B.

Subtract subtracts N-port B from N-port A.

Multiply multiplies N-port A with N-port B.

Divide divides N-port A by N-port B.

9.2 Cascade

The following cascade tools are available:

Cascade cascades $2N$-port A with N-port B or cascades 2-port A with 2-port B.

Decascade decascades $2N$-port A from N-port B or decascades 2-port A from 2-port B.

9.3 Index

The following index tools are available:

Change changes the port assignment of an S-parameter file (*.sdatb).

Reverse reverses the port assignment of an S-parameter file (*.sdatb).

Subset takes a subset of the ports of an S-parameter file (*.sdatb).

9.4 Data Set

The following data set tools are available:

Mean computes the mean of a data set.

Circle Fit computes the circle fit of a data set.

9.5 Merge

The merge tool merges two S-parameter files (*.sdatb) at a given frequency point.

9.6 Change Zr

The change Zr tool changes the reference impedance to a specified complex value in Ohm of an S-parameter data file (*.sdatb).

9.7 Data Converter

The data converter tool converts s-parameter data from one file format to another.

9.8 Interpolation

The interpolation tool interpolates a given S-parameter file (*.sdatb) to a frequency list which is specified by a file (*.fl).

9.9 Agilent Uncertainty Calculator

The Agilent uncertainty calculator computes uncertainties for S-parameter files (*.sdatb) using the Agilent Vector Network Analyzer Uncertainty Calculator, see http://www.agilent.com/find/na_calculator. Note that this option works only with 32 bit systems.

10 Script

The tabular page, called Script, provides a built-in Iron Python script engine, see Figure 32. The following user controls are available:

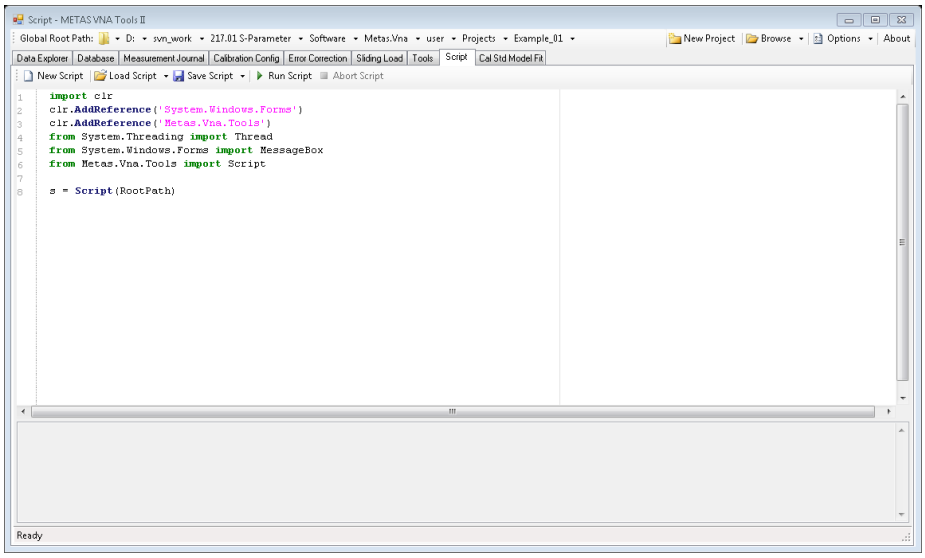


Figure 32: Script

New Script creates a new script.

Load Script loads an existing script from a file (*.py).

Save Script saves the script to a file (*.py).

Run Script executes the script.

Abort Script aborts the execution of the script.

Input field shows the script.

Output field shows the output of the script.

11 Calibration Standard Model Fit

The tabular page, called Cal Std Model Fit, computes the parameters of a calibration standard for an Agilent, Anritsu and Rohde Schwarz model, see Figure 33. The following user controls are available:

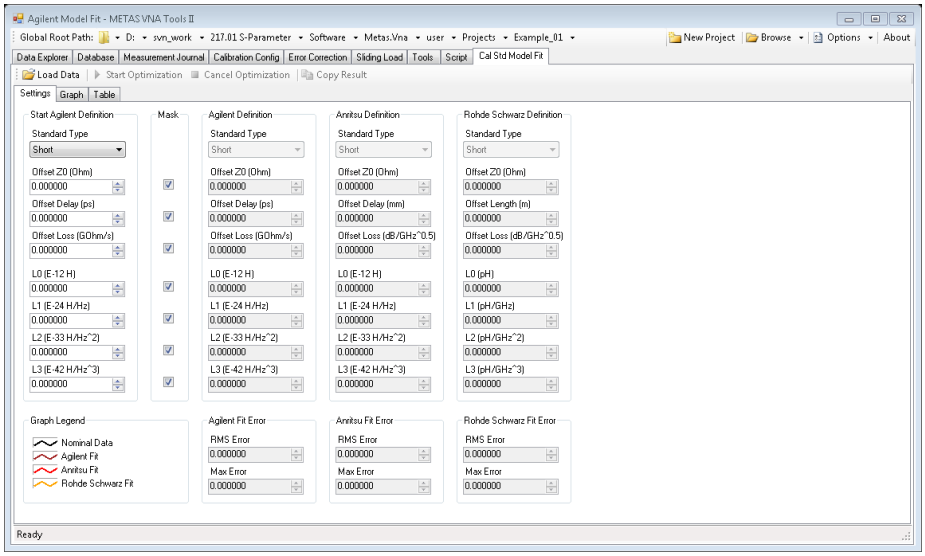


Figure 33: Calibration Standard Model Fit

Load Data loads S-parameter file (*.sdatb).

Start Optimization starts optimization of the selected parameters.

Cancel Optimization aborts optimization.

Copy Result copies the result to the clipboard.

Start Agilent Definition describes the start values for the optimization.

Mask selects optimization parameters.

Agilent Definition shows the result for the Agilent model.

Agilent Fit Error shows the fit error for the Agilent model.

Anritsu Definition shows the result for the Anritsu model.

Anritsu Fit Error shows the fit error for the Anritsu model.

Rohde Schwarz Definition shows the result for the Rohde Schwarz model.

Rohde Schwarz Fit Error shows the fit error for the Rohde Schwarz model.

A File Types

Table 5 shows the supported file types. S-Parameter Data files can only contain S-parameter data. In contrast VNA Data files can contain receiver values and ratios of receiver values.

Table 5: File types

Description	Extension
S-Parameter Data Binary	(.sdatb)
S-Parameter Data Touchstone	(.s*p)
S-Parameter Data Xml	(.sdatx)
VNA Calibration Config	(.calcfg)
VNA Calibration Data Binary	(.calb)
VNA Calibration Data Xml	(.calx)
VNA Data Binary	(.vdatb)
VNA Data CITI	(.cti;.citi)
VNA Data Xml	(.vdatx)
VNA Database Cable	(.cable)
VNA Database Calibration Standard	(.calstd)
VNA Database Connector	(.conn)
VNA Database VNA Device	(.vnadev)
VNA Error Correction Config	(.corcfg)
VNA Measurement Journal	(.vnalog)
VNA Sliding Load Config	(.slcfg)
Frequency List	(.fl)

B Naming Convention

The here described naming convention is meant as a help for the user. It is not required by VNA Tools II. Table 6 shows some examples for names of calibration standards and devices under test. Table 7 shows the naming convention for the

Table 6: DUT types

Description	Name
Open	'Open'
Short (n)	'Short[n]'
Flush Short	'FShort'
Load	'Load'
Sliding Load	'SLoad'
Mismatch	'MMatch'
Power Sensor	'PSensor'
Thru	'Thru'
Line l mm	'Line[l]mm'
Adapter	'Ada'
Matching Pad	'MPad'
Match Thru	'MThru'
Mismatch Thru	'MmThru'
Attenuator a dB	'Att[a]dB'
Step Attenuator a dB, selected state: s, x dB	'StepAtt[a]dB_[s]_[x]dB'
Splitter	'Splitter'
Coupler	'Coupler'

different connector types. Table 8 shows the naming convention for the gender of connectors. Figure 34 shows a typical project example.

Table 7: Connector types

Description	Name
1.0 mm Connector	'1.0mm'
1.85 mm Connector	'1.85mm'
2.4 mm Connector	'2.4mm'
2.92 mm Connector	'2.92mm'
3.5 mm Connector	'3.5mm'
7 mm Connector	'7mm'
Type N 50 Ω Connector	'N50'
Type N 75 Ω Connector	'N75'

Table 8: Gender of connectors

Description	Name
1-Port DUT female	'(f)'
1-Port DUT male	'(m)'
2-Port DUT female male	'(f-m)'
2-Port DUT male female	'(m-f)'
N-Port DUT female male male ...	'(f-m-m-...)'
N-Port DUT genderless	''

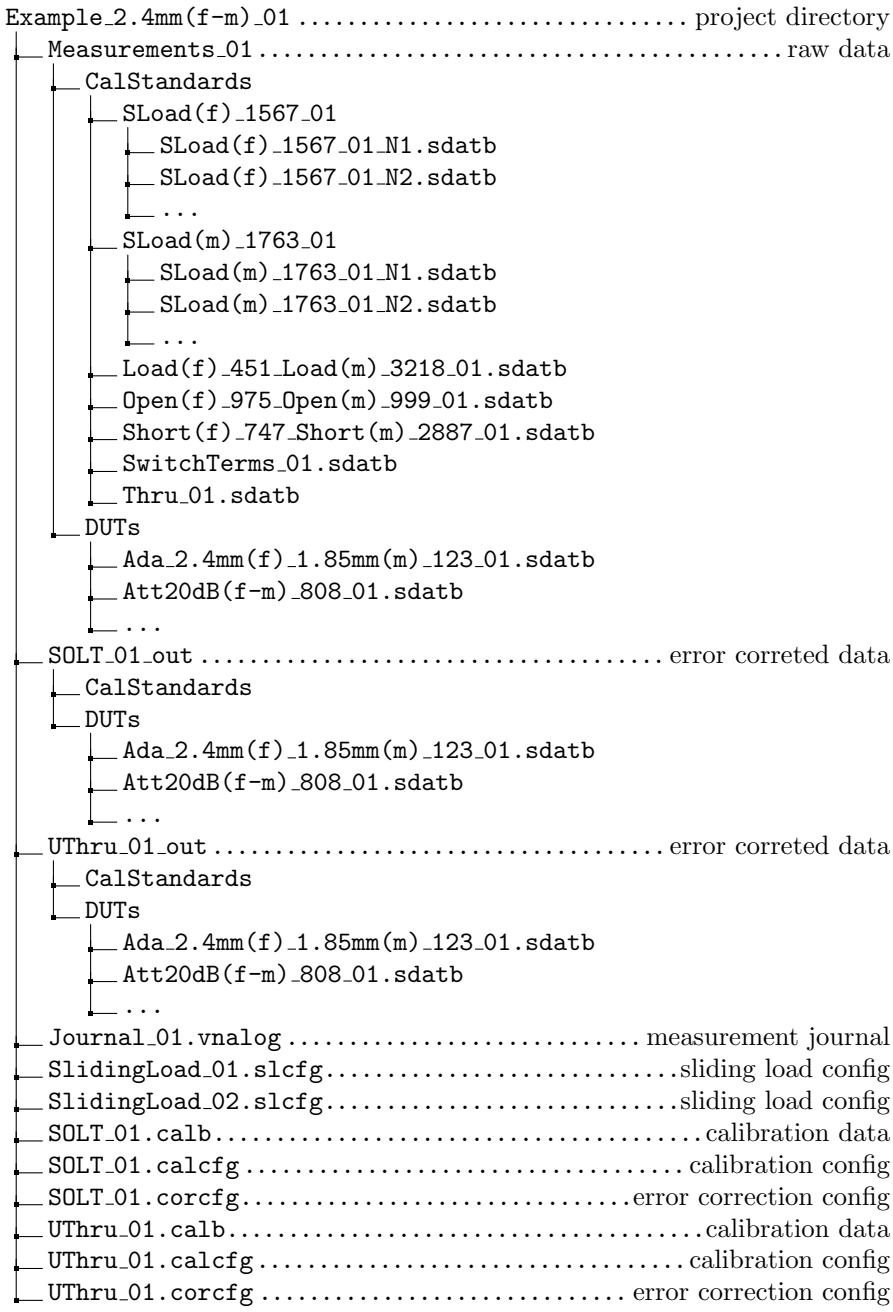


Figure 34: Tree view of a VNA Tools II project example

C Drivers

The following VNA's are supported by METAS VNA Tools II:

- Agilent ENA Series (Firmware E5061B A.02.06, E5071C A.09.60)
- Agilent PNA Series (Firmware A.09.40)
- Hewlett Packard 8510C (Firmware: 07.14 Aug 26 1998)
- Hewlett Packard 8751A (Firmware: 5.00 Mar 7 1993)
- Hewlett Packard 8753D (Firmware: 06.14 Oct 27 1997)
- Rohde & Schwarz ZNx Family (Firmware: 3.55)
- Rohde & Schwarz ZNB (Firmware: 1.30)

The following switch drivers are supported by METAS VNA Tools II:

- Agilent 11713A
- Agilent 11713C

The following electronic calibration units are supported:

- Agilent ECal connected to an Agilent PNA Series VNA.

Driver Development

For VNA's, switch drivers and electronic calibration units that are not supported yet, the user has the possibility to develop custom drivers that can be used with METAS VNA Tools II. This section describes the development of such drivers. The minimum software requirements for driver development in Microsoft Visual Studio for METAS VNA Tools II are:

- METAS VNA Tools II
  www.metas.ch/vnatools
- National Instruments VISA 5.0.3
  www.ni.com/visa
- Microsoft Visual C# 2008 Express Edition
  www.microsoft.com/express
  www.microsoft.com/visualstudio/en-us/products/2008-editions/express

The step by step procedure for the development of a custom driver for a VNA is as follows:

1. Check if the environment variable called `%Public%` is defined. This is the case under Microsoft Windows Vista and 7 but not under XP. Under Microsoft Windows XP you have to set the `%Public%` variable to `C:\Documents and Settings\All Users`.

2. Make sure the driver template `Metas.Instr.Driver.Template.zip` is in the template folder of Visual Studio under `%Userprofile%\Documents\Visual Studio 2008\Templates\ProjectTemplates`. Otherwise copy it from `%Public%\Documents\Metas.Instr\Drivers`.

3. Launch Microsoft Visual C# 2008 Express Edition.

4. Create new project from template in Visual Studio under File / New Project / My Templates / Metas.Instr.Driver.Template and name the project e.g. 'MyFirstVNA'.

5. Add a new class to the project under Project / Add Class and name it e.g. 'MyFirstVNA'.

6. This step describes the programming of the driver. Declare the class as public and implement the 'Metas.Instr.Driver.Vna.IVna' interface. See Figure 35 and MSDN website for how to implement an interface.

7. Compile project under Build / Build Solution. Make sure that the post-build event is successful and that the `MyFirstDriver.dll` is copied to `%Public%\Documents\Metas.Instr\Drivers`.

8. Test your driver directly in METAS VNA Tools II or debug it in Microsoft Visual Studio under Debug / Start Debugging.

For more help take a look at the already implemented drivers for METAS VNA Tools II under `%Public%\Documents\Metas.Instr\Drivers\Source`.

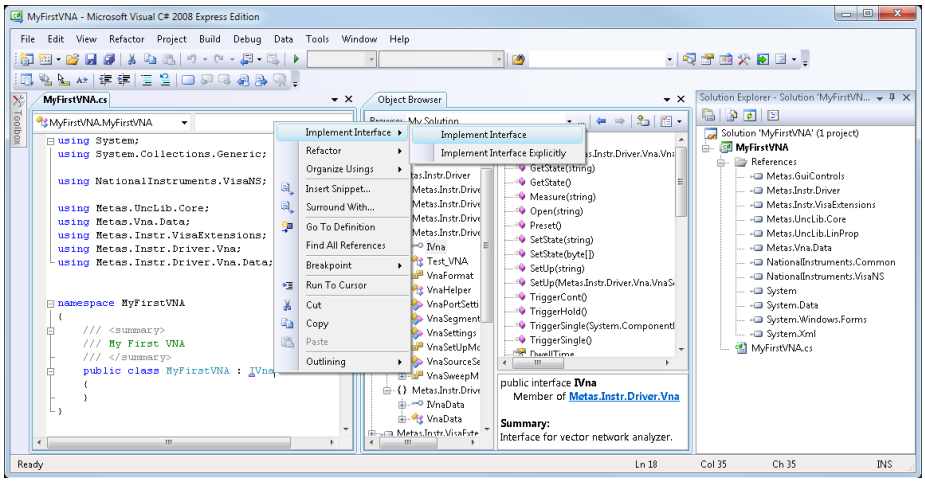


Figure 35: MyFirstVNA - Microsoft Visual C# 2008 Express Edition: Clicking with the right mouse button on IVna opens a content menu. Clicking on the menu item Implement Interface will create the basic class structure with all necessary properties and methods for the new driver.

D Further Reading

Documentations

- VNA Tools II - User Manual
- VNA Tools II - Math Reference
- Data Explorer - User Manual

Presentations

- VNA Tools II - Overview
- VNA Tools II - S-Parameter Uncertainty Calculation
- VNA Tools II - Data Format
- VNA Tools II - Optimization Calibration
- VNA Tools II - Step Attenuator Measurement
- VNA Tools II - Splitter Measurement

Tutorials and Screencasts

- VNA Tools II - Tutorial: Perform a SOLT Calibration with the Test VNA.

Websites

- www.metas.ch/vnatools
- www.metas.ch/unclib